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Energy and carbon impact of very low energy building

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Abstract
The main purpose of the current study is to investigate the impact associated with a wider introduction of very low energy buildings in Europe, especially for EU Member States (MS) which have elaborated plans for the future towards very low energy buildings. In the study, the resulting energy savings and CO_2 emission reduction from buildings constructed as very low energy buildings will be dealt with, taking into account the national energy-mix as well as national interpretation of very low energy buildings. In addition, the study seeks to obtain information on relevant national studies on very low energy buildings, including measures and programmes to promote such buildings and to remove barriers to their future development. In this context, education, training, and the public sector are areas of special interest.

In a recent study [1] we gathered a picture of the planned strategies in European countries regarding the implementation of requirements towards very low energy buildings (on passive house level or similar). This paper discusses results from a second survey on potential energy and CO_2 emission reductions if European MS shift towards very low energy buildings.

One of the prescribed actions on buildings in the EU Action Plan on Energy Efficiency [2] is for the Commission to develop a strategy for very low energy or passive houses (before 2009) towards a more widespread deployment of these building types by 2015. In the Commission proposal for the Energy Performance of Buildings Directive (EPBD) recast [3] MS will be required to draw up national plans for increasing the number of buildings for which both carbon dioxide emissions and primary energy consumption are low or equal to zero. The MS shall set targets for the minimum percentage which these buildings shall constitute of the total number of buildings in 2020. The targets shall be specified for both new and existing buildings as well as for buildings occupied by public authorities.

The current recast of the EPBD is therefore an excellent opportunity for the European Commission, the European Parliament and Council to show EU leadership in tackling both climate challenge, security of supply and fuel poverty by adopting ambitious requirements to develop very low energy and very low carbon emission buildings for both existing and new buildings as soon as possible. This study clearly shows that it is possible and that this move has started in Member States.

Introduction
This work was carried out to assist the European Commission, the Parliament and Council as well as Member States (MS) in the continued priority of developing a strategy for very low energy/carbon neutral buildings.

The work was carried out in two steps. The first step was to create an overview of the current situation in MS for implementing very low energy buildings (VLEB) and the strategies to make this become the standard. The study showed that several MS have already set targets for very low energy or carbon neutral buildings however, also that some countries have made no progress in this direction.

The definition of VLEB varies significantly across Europe, not only in terms of the allowed absolute level of energy consumption in a low energy building, but also in the energy flows included in the minimum requirements. Further the national calculation methods vary from country to country, which makes it almost impossible to compare the absolute values of the energy requirements between MS. The detailed results of the first study are reported in [1].

THE SECOND PHASE STUDY

The main purpose of this second survey was to investigate the impacts associated with a wider introduction of VLEB in five selected European MS [4]. Denmark, France, Germany, The Netherlands, and United Kingdom were selected as they today have a national strategy for all new buildings to comply with a national standard for VLEB. The calculations referred in this paper use the proposed national definitions that new buildings should comply with as stated by the official sources in the five countries.

First, the energy and CO_2 savings per m^2 were estimated from current requirements to future national standards on VLEB. Second, two different scenarios was calculated, one based on stepwise moving towards VLEB for all new buildings and one based on directly moving towards a very low energy standard for all new buildings. However, it showed up to be much more difficult than expected to collect the needed national information, so that data given in this report can only be taken as indicative estimates. Finally, an overview of established promotion instruments for VLEB in the analysed MS is presented with some pro and cons.

A questionnaire elaborated to collect further information was developed and distributed to official representatives of the selected countries. The questions in this were about national statistics needed to calculate energy and CO_2 emission reduction. The statistics required were about current energy mix for energy used in buildings, energy mix expected for energy used in future VLEB, building construction statistic, etc. Also the existence of national studies evaluating the impact of a wider introduction of VLEB focusing on the cost-effectiveness, potential for energy and CO_2 emission reduction and job creation were required. Finally the questionnaire asked for knowledge about instruments used to promote VLEBs.

A general remark, which needs to be given is that for some countries, mainly UK, the required data did not exist and best estimate was used. This leads to a general wish for a better and more consistent data collection at national level is highly recommended in order to estimate and evaluate the impact from regulatory measures.

Method

The survey was conducted by the Danish Building Research Institute (Aalborg University) with the assistance of UK-ACE, BuildDesk and EuroACE regarding collection of data. The full report [4] is available at www.euroace.org and www.sbi.dk. The questionnaire was circulated late spring 2008 to official representatives from the selected MS, and the information was updated in early 2009.

In the questionnaire, the term "very low energy building" is used. In the context of this survey, the term covers low energy buildings, low carbon buildings and passive houses as well meaning buildings designed to a significantly higher standard of energy performance than the minimum required by the national building regulations.

From the responses, combined with input gathered from the first phase study, it was possible to obtain the information needed to calculate the energy saving and CO_2 emission reduction from a development towards VLEB. The answers have been analysed in the best possible way and supplemented by knowledge from the project group.

Results

MS STRATEGIES TOWARDS VERY LOW ENERGY BUILDINGS

The majority of countries who responded to the questionnaire in the first study either have an official or a non-governmental (NGO) definition of VLEB. Many countries have plans for their next revision of the energy requirements, and at least eight countries have a schedule for introducing the level of VLEB as the minimum requirement for all new buildings in their building regulation.

By 2016 the United Kingdom (England and Wales) aims to have zero-carbon requirements for heating, lighting, domestic hot water and all appliances. By 2020 Norway aims to have requirements similar to the German passive house level. The requirements in Denmark will by 2020 be reduced by 75% compared with the minimum level from 2006. By 2020 France, Germany, and the Netherlands aim to require all new buildings to be either energy neutral or energy producing. More details about the national plans can be found in [3].

Additionally several counties have set goals for improving energy efficiency of the existing building stock, albeit expressed in very different ways. In France the Grenelle agreement sets targets. Germany has initiated a financial support program linked to a clear target, countries like the Netherlands, Belgium (Flanders), Spain, Hungary, Denmark, and others have introduced energy requirements for buildings in conjunction with renovation in their legislation.

ENERGY REQUIREMENTS FOR VERY LOW ENERGY BUILDING

Comparison of the minimum energy performance requirements between MS is not directly possible as the assumptions and basis for calculating energy performance differ. For instance, energy performance can be calculated by heated floor area, habitable area, or gross floor area which can easily result in deviations of 10-20%, especially in highly insulated buildings.

Furthermore, the calculation methodology differs regarding energy flows included in the calculation of the energy performance as well as the factor used to convert from final to primary energy. Figure 1 illustrates some of the different national definitions used for VLEB and the conversion factors used. No changes in the conversion factors and energy flows have been anticipated in the estimate of savings when going from current level of energy requirements to the national definitions of VLEB.

SCENARIOS FOR ENERGY SAVINGS

Energy and CO_2 savings per m^2 have been estimated for MS moving from current energy requirements to the future national standard of VLEB. Based on the estimated savings per m^2, two different scenarios have been calculated, one moving directly to the very low energy standard for all new buildings

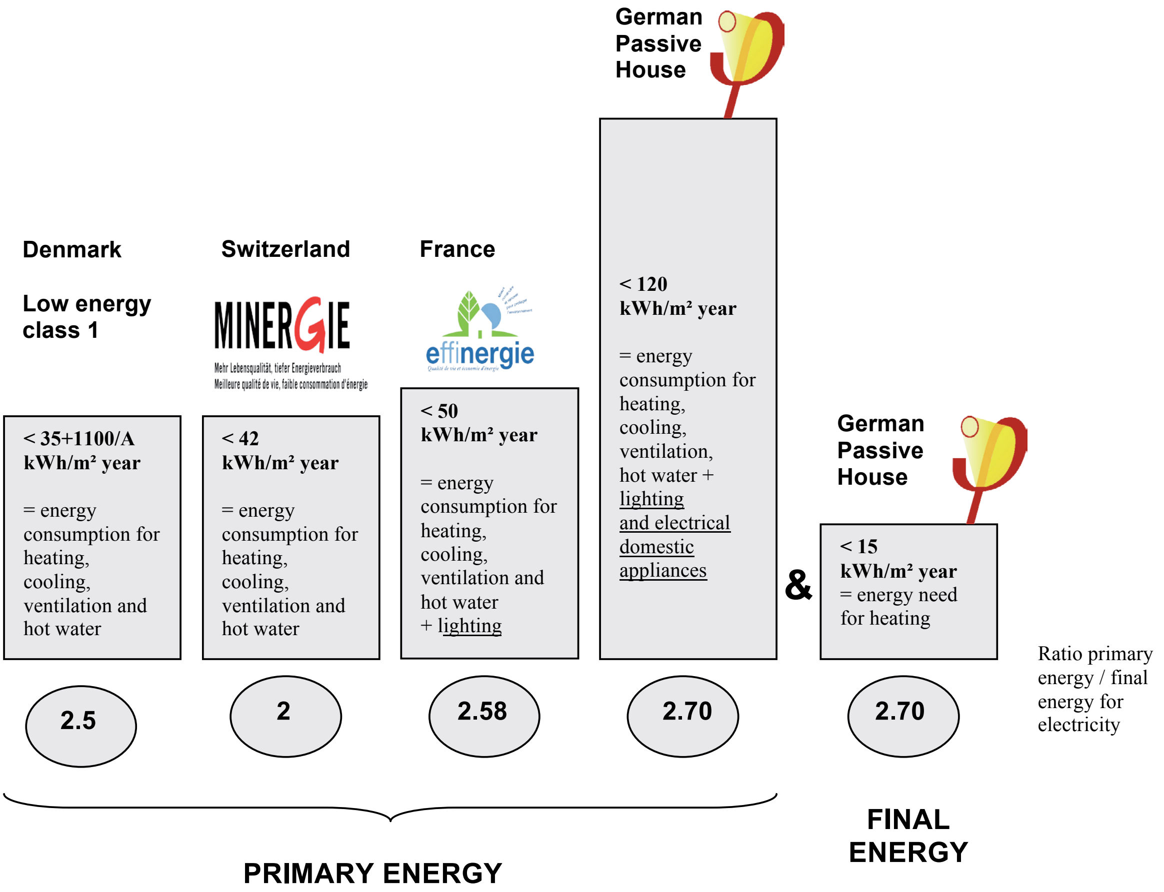

Figure 1. Examples of national definitions used for VLEB in DK, Switzerland, France and Germany. The Dutch energy target is expressed in a dimensionless constant EPC, and the UK limits are set on the CO_2 emission.

Country/year	2009	2010	2012	2013	2015	2016	2020
Denmark		-25 %[1)]			-50 %[1)]		-75 %[1)]
France			LEB[2)]				E+
Germany	-30 %		-30% [3)]				NFFB
Netherlands		-25 %			-50% [4)]		ENB
United Kingdom		-25 %		-44%[4)]		NZEB	

1) Percentage of the 2006 minimum level, 2) Effinergie standard, 3) Percentage of the 2009 minimum level, 4) Passive House level.

Figure 2. Planned introduction of low energy standards as minimum requirements in MS building regulations. LEB: Low Energy Buildings. E+: Energy positive buildings. NFFB: Buildings to operate without fossil fuels. ENB: Energy Neutral Buildings. NZEB: 0 net. CO_2, incl. heating, lighting domestic hot water and all appliances.

and one moving stepwise to VLEB for new buildings, following the national pathway illustrated in figure 2.

- The first scenario has been calculated under the assumption that all new buildings from January 2009 are constructed according to the national standard for VLEB. The energy savings per m^2 is estimated in table 2 and comes by subtracting the energy requirements in the current building regulation by the energy requirements for VLEB. The savings were accumulated over the period from 2009 to 2020 in table 6.
- The second scenario shows the savings potential resulting from MS implementing the announced national strategy towards VLEB in their building requirements in steps as described in figure 2. Savings are accumulated over the period from 2009 to 2020 in table 6.

Table 1. Delivered energy consumption - national minimum energy requirements in building regulation for different kinds of new buildings, in kWh/m² per year. The values are expressed in terms of primary energy with a factor of 2.5-2.7 for electricity and 1 for all other energy sources.

Building type	Denmark	France	Germany	Netherlands	United Kingdom
Single family houses of different types	90	90-180	80-150	100-130	85-95
Apartment blocks	75	80-150	n/a	95-100	n/a
Non domestic buildings – excluding hospitals	80-150	75-180	80-150	120-315	170-270

Table 2. Delivered energy consumption following the national VLEB definition, in kWh/m² per year. For further information about the level of current energy requirements and the data behind table 2 see ref. [4].

Building type	Denmark	France	Germany 1)	Netherlands	United Kingdom 2)
Single family houses of different types	45	40-65	42	50-65*	50
Apartment blocks	37	40-60	42	50	n/a
Non domestic buildings – excluding hospitals	37-50	30-75	42	60-158	95-151

1) The values are approximately the same as stated in the KfW40 standard.

2) The values for UK might be too low as the calculation method in the UK is too optimistic in the prescribed assumptions according to: www.aecb.net/PDFs/conference07/AECB%202007%20AGM%20Workshop%20Pres%20070707.ppt (including appliances, lighting, cooking, HVAC fans/pumps, DHW and space heating).

Energy savings when moving from building regulation minimum requirements to very low energy requirements

For each of the five MS data was compiled to make a calculation of the energy savings if shifting from buildings built according to the present minimum building regulation requirements to VLEB according to the national definition.

For each country the savings in kWh/m² has been calculated/estimated based on the national requirements and definitions. In United Kingdom and Netherlands the requirements are not given in kWh/m², but in CO_2 emission and as the Energy Performance Constant (the EPC value) which means that in these cases it was necessary to estimate the corresponding values in kWh/m². Table 3 gives the estimated annually energy savings per m² (as delivered energy) shown for the five considered countries.

For more details and assumptions used to estimate the numbers in table 1, see ref. [4]

CONSTRUCTION ACTIVITY

In order to bring energy saving per m² heated area into national energy savings, valid figures on construction activity were needed. For this purpose, the respondents looked carefully at national statistics concerning annual construction activity distributed on types of new buildings. Table 4 gives an overview of the figures used to estimate the accumulated savings until year 2020.

RESULTING ENERGY SAVINGS FROM THE TWO SCENARIOS

The energy savings per m² constructed VLEB can be extrapolated to the entire country and with some caution to the whole Europe. The construction activity in the MS is thus an important figure to be able to carry out this extrapolation. Energy savings per m² are multiplied with the average construction activity in the MS for the different building types. This may not necessarily give a correct picture as the construction activity in some MS has been anything but "normal" over the past years. Among others the activity has been much higher than normal in countries like France, Denmark and Spain while in Germany on the other hand, the construction activity has been below the normal level. The estimated energy savings are shown in table 5 and 6.

If the five MS were able to make VLEB become minimum standard for all new buildings from January 2009 instead of following the announced partway described in figure 2, the additional energy savings in 2020 for all five MS will be 906 PJ given the assuming that the current construction activity is unchanged until 2020.

CARBON CALCULATION

A CO_2 calculator was set up for each of the five MS. The calculator has been calibrated according to the energy mix in each MS, meaning that the national energy break down, must be known in order to perform a valid CO_2 emission calculation. Additionally, the CO_2 content of each of the energy carrier – especially district heating and electricity as theses differs from MS to MS - must be known.

The national energy statistics have been investigated for energy breakdowns concerning the actual energy consumption in residential and non-residential buildings as well as average CO_2 emission concerning national energy consumption. In the Netherlands it was not possible to obtain the energy mix for the building sector energy consumption and the total energy break down have been used as being representative. Further, the na-

Table 3. Standard energy savings per m² heated area annually in Member States as a consequence of changing to VLEB, calculated as difference in energy requirement of current building regulation and national VLEB standard, in kWh/m² per year. For further information behind the data stated in table 2 see ref. [4].

Building type	Denmark	France	Germany	Netherlands	United Kingdom
Single family houses of different types	45	83	38-108 (73)	50-65 (57)	40
Apartment blocks	37	65	38-108 (73)	50	n/a
Non domestic buildings – excluding hospitals	42-50 (46)	45-105 (75)	38-108 (73)	60-158 (109)	75-119 97

Numbers in brackets are the average values which have been used in the calculation.

Table 4. Average construction activity (m²) based on the annual activity over the past three years in the five MS.

Building type	Denmark	France	Germany 1)	Netherlands	United Kingdom 2)
Single family houses of different types	2.467.588	24.274.047	4.675.250	6.224.530	18.130.133
Apartment blocks	740.723	10.001.600	2.026.500	2.658.180	-
Non domestic buildings - excluding hospitals	1.394.107	9.400.001	25.789.250	1.972.500	18.000.000
Total	4.849.888	44.975.647	32.491.000	10.855.210	36.130.133

1) The German figures indicate that the German construction market in the period considered has been very low.
2) Industry estimate: UK has no statistics showing the actual constructed m² the number stated for single family houses is based on the numbers of completed dwellings and an average size of 87 m². Prior to the recent 'credit crunch', the UK Government predicts that 9000 non-domestic buildings will be built in 2008. The average size of these buildings is estimated to be 2000 m² equal to a total of 18.000.000 m².

Table 5. Potential energy savings between current Building Code minimum requirements and VLEB requirements in TJ per year.

Building type	Denmark	France	Germany	Netherlands	United Kingdom
Single family houses of different types	400	7 253	1 229	1 277	2 628
Apartment blocks	99	2 340	533	478	-
Non-domestic buildings - excluding hospitals	272	2 538	6 777	774	6 286
Total	771	12 131	1316	125229	8 914

Table 6. Accumulated energy savings (TJ) in 2020 in Member States as a consequence of stepwise or one-step change to VLEB using the data in tables 3-4.

Building type		Denmark	France	Germany 1)	Netherlands	United Kingdom
Domestic buildings						
	stepwise	17 213	343 792	66 798	61.425	112 773
	one step	32 895	630 285	116 241	115.829	171 732
Non domestic buildings						
	stepwise	9 515	91 368	257 050	27 010	271 862
	one step	17 942	167 508	447 309	50 967	413 994
The additional energy savings by changing to VLEB standard, January 2009 instead of a stepwise change:						
		24 109	362 633	239 702	78 362	201.091

1) For Germany the standard savings in table 3 have been used to calculate the accumulated "one-step" saving where the "stepwise" saving is calculated based on the planned tightening described in figure 2.

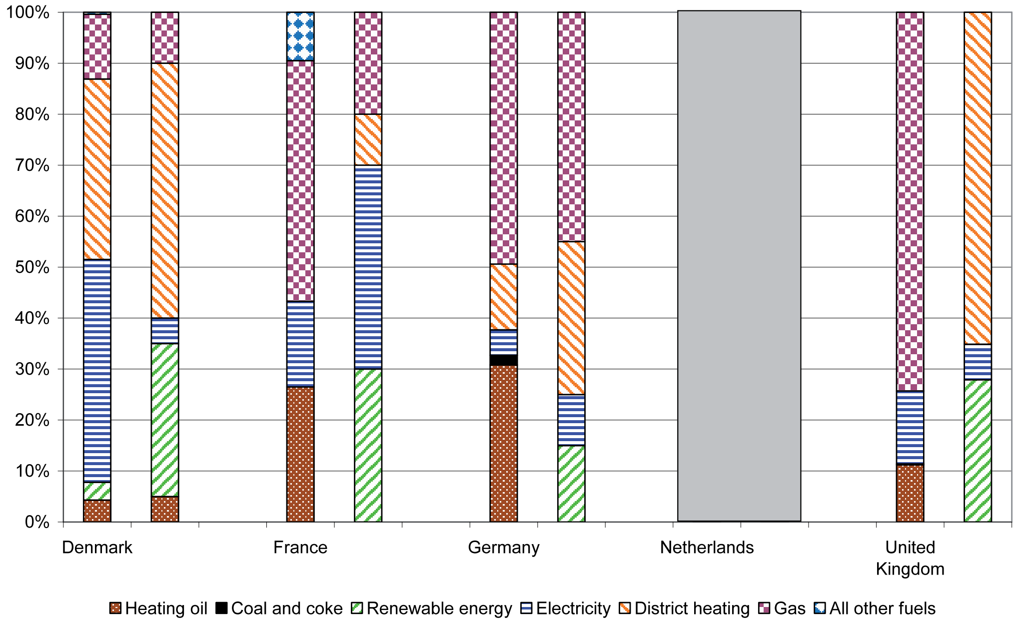

Figure 3. Present (left) and future (right) energy mix for space heating in residential buildings in the five member states. The energy mix for the Netherlands is based on the average energy mix for the country, e.g. including industry, transport, space heating and cooling, lighting etc. Similar data has been collected for the non-residential sector, see ref. [4].

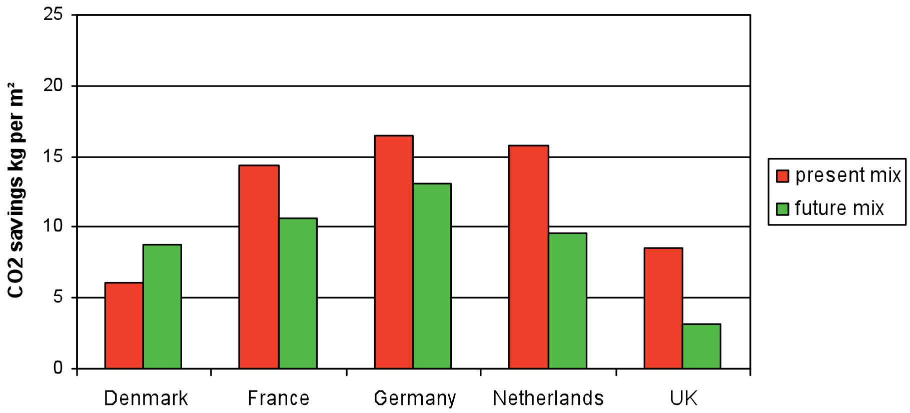

Figure 4. CO_2 savings per constructed m² of residential VLEB when moving from the present building regulation.

tional respondents were asked to estimate the future energy mix in new VLEB as the energy mix most likely will change compared to today's mix, figure 3.

CO_2 EMISSION REDUCTION FROM SHIFTING TOWARDS VLEB

Based on the energy consumption in new, standard residential buildings and the expected energy consumption in VLEB and the CO_2 emission reduction per m² has been estimated for each of the five MS.

The calculated saving in energy use and CO_2 emission will of course depend on a number of parameters and conditions:

- level of energy efficiency in the new building stock,
- level of energy efficiency in the VLEB stock,
- differences in energy mix and thus average CO_2 emissions,
- different climate conditions.

All together, these parameters and different conditions make up rather big differences in the potential CO_2 reduction from MS to MS.

Figure 4 and 5 shown the calculated CO_2 emission reduction from changing to VLEB for the five considered MS based on the annually energy savings per m² heated area.

Regarding the residential sector, France, Germany, and the Netherlands will experience a reduction in CO_2 emissions per newly constructed m² of VLEB compared to Denmark and the United Kingdom. This is due to the starting point where the energy requirements in the French, Dutch, and German building regulation are lower than in the two other countries, while the energy consumption in future VLEB is of the same order of magnitude.

The increase in CO_2-emission for future Danish residential VLEB compared to the present energy mix of energy carriers is due to the assumption that future buildings will have a higher ratio of electricity-based heat pumps for space heating and thus

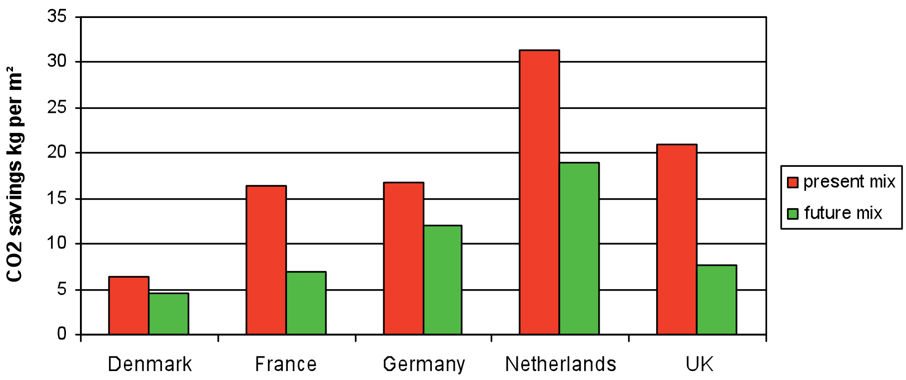

Figure 5. CO_2 savings per constructed m² of non-residential VLEB when moving from present building regulation.

Table 7. Annual CO_2 emission reduction per m² distributed on the five MS if changing all building activity from standard minimum Building Regulation requirements to VLEB (future energy mix).

	CO_2 emission reduction	Construction activity[1)] annually	Annual CO_2 emission reduction
	kg/m²	m²	Tonnes
Denmark			
residential	8.8	3 208 311	28 000
non-residential	4.5	1 641 577	7 000
total			35 000
France			
residential	10.7	34 275 647	368 000
non-residential	6.9	9 400 000	65 000
total			433 000
Germany			
residential	13.1	6 701 750	88 000
non-residential	12.1	25 789 250	313 000
total			401 000
Netherlands			
residential	9.5	8 882 710	85 000
non-residential	18.9	1 972 500	37 000
total			122 000
United Kingdom			
residential	3.2	18 252 000	58 000
non-residential	7.7	18 000 000	139 000
total			197 000

1) For the construction activity the average of the resent 3-5 years construction activity has been used.

increased electricity consumption. Today, direct use of electricity is almost not used for heating in Denmark.

In the Danish case the calculation shows a total saving of 0.8 PJ or 35,000 ton CO_2 per year (table 5 and 7), which is only 0.3% of the total energy used for heating and only 1% of the savings which can be gained from upgrading the energy performance of the existing building stock according to [6].

The future energy mix has been used to estimate the total, annual CO_2 emission reduction. The total annual CO_2 emission reduction for the five MS becomes thus 1.2 Mt CO_2.

Promotion of VLEB

The main instrument in promotion of VLEB used in all the five considered MS includes is timely announcement of further tightening of energy performance requirements. This is very valuable for the industry as it is used to prepare for and develop technical solutions in good time. Demonstration projects are also used and considered being very valuable in order to learn more about VLEB and CO_2 neutral buildings. Another very important measure to drive building industry towards VLEB and zero CO_2 buildings is tax incentives and soft loans, which is used in several countries. It is worthwhile to point out that

Table 8. Promotion of low energy buildings.

	Denmark	France	Germany	Netherlands	United Kingdom
Timely announcement	X	X	X	X	X
Demonstration projects	X	X	X	X	
Tax incentives		X			X
Soft loans		X	X	X	X
Local planning	X			X	

such measures have been used in countries like Germany, Austria, and Belgium to facilitate introduction of low energy and passive housing. Such measures have made low energy buildings and low CO_2 buildings common standard in Austria. Local planning where regions are taking the lead and go further than required in building regulation is also seen as a promotion instrument in the same way as demonstration projects. A summary of the promotion instruments are shown in table 8.

Education and training

Education and training are dealt with in all the considered MS. However, Germany seems to be the most advanced with special focus on sharing knowledge about best practice[1]. Both 'Zukunft Haus' and the German Energy Agency (dena) run training, skills and best practice programmes for VLEB. However, the emphasis is still firmly on the residential sector.

Conclusion and recommendations

Many countries have announced their plans for the forthcoming revisions of their energy requirements, and several countries have thus targets for new energy requirement in 2015 and 2020. A long-term objective is an effective and needed instrument to achieve very low energy buildings, resulting in energy and CO_2 emission savings. Additionally it provides a valuable tool and guideline for the construction sector to prepare for the further development and implementation of the strategy.

It is important to stress the need for all MS to develop a national strategy towards making the level of VLEB become the standard for all new building as soon as possible.

A proper market transformation towards VLEB is a challenge for all stakeholders in the building sector. However, an increasing number of the MS have started this process as they realise that this is one of the needed solutions to tackle the current and future challenges like climate change, energy supply, and fuel poverty.

In order to speed up the transformation process, it is essential to learn from those countries that have already gone rather far in this process.

It is important that the European institutions continue to guide this development through EU legislation like the current EPBD recast, and require the MS to develop a national strategy towards this level of energy performance to become the standard as quickly as possible as well as setting up ambitious plans for how to tackle the challenge of making the existing building stock equally energy efficient.

A clear and ambitious strategy for improved energy efficiency of existing buildings is necessary if energy consumption is to be reduced significantly in the near future. The lifetime of buildings ranges between 50 and 100 years, and improvement of the existing building stock will thus have a much higher impact than tightening the requirements only for new buildings. However, the experience gained from the new VLEB will help move the existing building stock in the same direction, as technologies and way of constructing VLEB become the natural reference for existing building as well.

Lessons from Austria, that have been one of the leading countries in the development of low energy buildings, shows that economical and financial incentivises to drive the development towards low energy buildings are needed.

In order to secure reduction in CO_2 emissions it is also of great importance to focus on the energy mix for new VLEB, as a change towards a higher use of electricity may lead to increased CO_2 emissions, as in Denmark.

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1. see www.zukunft-haus.info/de/projekte/niedrigenergiehaus-im-bestand.html for the residential sector, and www.zukunft-haus.info/de/projekte/niedrigenergiehaus-im-bestand-fuer-schulen.html for the schools sector